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Symposium on High Purity Water Corrosion. Special Technical Pubn. No. 179, 1956, 56 pp. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Papers presented during the ASTM June, 1955, meeting at Atlantic City. The symposium was sponsored by Committee D-19 on Industrial Water. Titles of papers are: Preparation and Maintenance of High-Purity Water, F. N. Alquist; Use of Water in Atomic Reactors, H. W. Huntley and S. Untermyer; Influence of Water Composition on Corrosion in High-Temperature High-Purity Water, Donald V. ...; James M. Seamon and ...; Effect of Material Composition on High Temperature Water Corrosion, H. Roebuck; Special Corrosion of Carbon and Low Alloy Steels, U. Blaser and J. J. C. ... Discussions are included.

The Corrosion Behavior of Some Stainless Steel-Boron Alloys in High Temperature Water. DONALD C. BELOUIN AND ULRICH MERTEN. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Publication, KAPL-M-UM-5, Feb. 7, 1956, 15 pp. Available from Office of Technical Services, Washington, D. C.

A number of 18-24 stainless steels containing up to 2.3 wt. % boron were exposed to static, high-purity water at 600 and 680 F. The results indicate only a small change in corrosion resistance under these conditions as a result of boron additions. (auth)

Factors in the Evaluation of the Corrosivity of Waters. (In Italian.) G. BOMBARA AND F. GIANNI. *Metallurgia Italiana*, 48, 503-512 (1956) Nov.

Natural waters and inhibited waters and solutions studied for effects on ordinary construction steel at ambient temperature. Concludes impossibility of defining corrosivity of an electrolytic medium on a given metal unless all corrosion conditions specified; that most adequate method appears to be determination of break point on cathode polarization curve. 11 references.

Corrosion of Iron and Steel by Water. Influence of pH, Oxidizing and Reducing Agents, Chlorides, Phosphates, and Temperature. (In French.) MARCEL POURBAIX. Cebelcor, Technical Report No. 40, May, 1956, pp. 192-208. Centre Belge d'Etude de la Corrosion, 21 Rue des Drapiers, Brussels, Belgium.

Influence of these factors on the corrosive properties of ordinary and industrial waters in contact with iron and unalloyed steels was studied in connection with research on chemical and electrochemical equilibrium and speed of the reactions. Correct processes for anticorrosive treatment of water and metal were suggested.

The Corrosion Behavior of Some Zirconium- and Titanium-Base Boron Alloys in High Temperature Water. DONALD C. BELOUIN AND ULRICH MERTEN. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-M-UM-6, June 15, 1956, 12 pp. Available from Office of Technical Services, Washington, D. C.

A number of zirconium- and titanium-base alloys containing up to 2% boron were exposed to high purity water at 600 and 680° F. The results indicate that a high degree of corrosion resistance is attainable in the titanium-boron alloys and that the addition of 0.4% boron to zircaloy-2 increases its corrosion rate, but not drastically. (auth)

The Corrosion of Mild Steel by High Temperature Water. J. N. WANKLYN. Gt. Brit. Atomic Energy Research Establishment, Harwell, Berks, England, Rept. M/M-116, May, 1956, 8 pp.

Methods of measuring and expressing the corrosion of carbon steel by high temperature water are discussed. Recent information on the influence of a number of factors is summarized. (auth).

Aluminum Alloys for Handling High-Purity Water. W. W. BINGER and C. M. MARSTILLER. *Corrosion*, 13, No. 9, 591t-596t (1957) Sept.

Aluminum alloys have been used for more than 20 years for storage and distribution systems handling distilled water. Recently, it became possible to investigate experience with some 30 distilled water systems which had been in use for various periods of time up to 24 years. Many of these systems had been made entirely of aluminum. Several were composed entirely of tinned copper or brass and others were made up of a combination of materials including aluminum.

Results indicate that aluminum alloy storage tanks, tubing, fittings and valves are highly satisfactory for handling distilled water and do not cause significant contamination of the water being handled.

The increased use of the ion exchange method for purifying water has required equipment fabricated from materials in which such a water could be handled with a minimum of pick-up and discoloration. Since many processes require large quantities of a water of very low total solids content, it was natural to consider aluminum alloys for the fabrication of storage tanks and piping for handling demineralized water. 14191

Symposium on High Purity Water Corrosion. Special Technical Pubn. No. 179, 1956, 56 pp. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Papers presented during the ASTM June, 1955, meeting at Atlantic City. The symposium was sponsored by Committee D-19 on Industrial Water. Titles of papers are: Preparation and Maintenance of High-Purity Water, F. N. Alquist; Use of Water in Atomic Reactors, H. W. Huntley; S. Untermyer; Influence of Water Composition on Corrosion in High-Temperature, High-Purity Water, Donald M. Wroughton, James M. Seamon and Paul E. Brown; Effect of Material Composition in High Temperature Water Corrosion, A. H. Roebuck; Special Corrosion Study of Carbon and Low Alloy Steels, R. U. Blaser and J. J. Owens. Discussions are included. 12749

The Corrosion of Iron in High-Temperature Water. Part II. Kirkendall Experiments. D. L. DOUGLAS and F. C. ZYZES. *Corrosion*, 13, No. 7, 433t-436t (1957) July.

Kirkendall-type experiments were carried out in order to identify the ion species diffusing through the magnetite film formed on corrosion of iron in high temperature water. Iron disks were painted with a slurry of Ni^{2+} , and the surface activity was measured. After corrosion the activity decreased. This decrease is shown to be most readily explained by a covering of Ni^{2+} by magnetite formed as iron ions diffuse outward from the metal-oxide interface to the oxide-water interface. 13871

Manual on Industrial Water. ASTM Special Technical Publication 148-B, Third Printing, 1956, 502 pp. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.

The significant increase in the use of water for industrial processes makes the latest printing of the Manual on Industrial Water, a timely addition to the literature. Sponsored by ASTM Committee D-19 on Industrial Water, the manual contains a complete appendix in addition to a comprehensive discussion of water, its uses, treatment, sampling, analysis and difficulties caused by it.

The appendix lists ASTM standards relating to industrial water. It contains five methods of sampling, 41 standards, four methods of analysis, three standards for methods of reporting results, six standards for methods of test, a glossary of terms, a list of industrial water requirements and a bibliography.

Included in the latest printing are seven new methods and one important revision. Two additional proposed methods are published as additional information. No changes have been made in the chapters of the manual. 13495

The Storage of High Purity Water. RICHARD R. DLESK. *Corrosion*, 13, No. 9, 585t-588t (1957) Sept.

A need is developing in industry for water of higher and higher purity. As the purity of the water increases, the storing of it becomes an increasingly difficult problem. In order to mitigate this problem, investigations and appraisals of new protective measures for existing steel tanks were made, and some were applied to actual installations. Protective coatings discussed include red lead paint, metallic zinc paint, synthetic rubber, nickel-phosphorous-alloy coating, heavy electroplated nickel and metalized aluminum coatings.

Aluminum, as a construction material for storage facilities, was evaluated in laboratory and field tests. These tests resulted in the construction of four 44,000-gallon aluminum storage tanks. Data were reported to show the electrical resistance of a film developed on 3003 aluminum alloy in tap water, distilled water and demineralized water.

Corrosion Control Aspects of Circulating Water Treatment. J.M. BROOKE, B.G. WITT. *Corrosion* v 17 n 8 Aug 1961 p 22-3, 25. Major objectives in treating cooling water are reviewed and steps suggested for controlling scale formation; effects of cooling tower operation on water and water treatments are considered and effects of pH, blowdown control and low alkalinity makeup described; factors involved in choosing water treatment system; some examples of successful systems.

Corrosion of Metals in Sea Water. F.W. FINE. US Dept Interior—Office of Saline Water—Research & Development Progress Report 46 Dec 1960 59 p. (Available from OTA, Washington 25, DC PB 171344, \$1.75). Results of investigation intended to provide special knowledge on corrosion of metals utilized in design of installations for sea water conversion by: distillation, distillation using vapor-compression multi-stage flash evaporators, distillation with vapor reheat, distillation without use of metallic heating surfaces, vapor compression using forced circulation, etc processes.

Some Loop Experiments in NRX Reaction to Study the Corrosion of Mild Steel by Flowing Water at 90 F. G. M. ALLISON. Atomic Energy of Canada Ltd., Chalk River Project. November, 1956. 24 pp. Available from: Scientific Document Distribution Office, Atomic Energy of Canada, Ltd., Chalk River, Ontario, Canada.

The water conditions necessary for minimum corrosion in the mild steel thermal shield recirculating systems in NRX and NRU were studied. The chemical and corrosion results obtained by operating three mild steel loops in which water at 85 to 95 F was recirculated through test sections located in J-rod positions in the NRX reactor are reported. Lowest corrosion rates were found when the water was maintained at pH 10.5 with or without oxygen being present. In both cases the corrosion was general in nature and no pitting occurred. At pH 7 with oxygen present in the water severe pitting took place and the corrosion rate was several times higher than similar conditions without oxygen in the water. Under oxygen-free conditions the corrosion product was Fe_3O_4 . At pH 7 and with 3 to 5 ppm of oxygen in the water the corrosion product was a mixture of Fe_3O_4 and $\gamma\text{-Fe}_2\text{O}_3$. At high pH with oxygen present Fe_2O_3 predominated with some traces of Fe_3O_4 . The systems tested may be listed in order of increasing corrosiveness: high pH with or without oxygen in the water < water at pH 7 with no oxygen present and continual purification < water with no oxygen present and no purification or pH control < water at pH 7 with 3 to 5 ppm of oxygen present. (auth).

Corrosion of Type 2S Aluminum in Distilled Water. G. M. INMAN and J. J. SHYNE. North American Aviation, Inc., Downey, Calif. U. S. Atomic Energy Comm. Pubn., NAA-SR-Memo-26, April 10, 1951 (Declassified April 13, 1956), 15 pp. Available from: Office of Technical Services, Washington, D. C.

Corrosion of 2S aluminum in contact with distilled water at room temperature presented an unexpected and serious problem during experiments with an exponential assembly. Effective coatings were developed for the aluminum tubing surfaces affected, which could provide protection against corrosion up to at least 80 C. The coatings have safely low neutron absorption cross sections. The probable mechanism of corrosion is briefly discussed. (auth).

Effect of Material Composition in High-Temperature Water Corrosion. A. H. ROEBAUCK. Paper before Am. Soc. Testing Materials Symp. on High-Purity Water Corrosion, Atlantic City, June 28, 1955. ASTM Special Technical Publication No. 179, 1956, 27-34; disc., 35-36.

Corrosion characteristics of number of materials were studied under variety of conditions, to select materials for high temperature water systems operating with maximum water purity and minimum corrosion product contamination. Compositions of highest corrosion are cobalt alloys, platinum, austenitic, heat-resisting and precipitation hardening stainless steels, titanium, zirconium and hafnium; those of intermediate resistance are aluminum and aluminum alloys, chromium, 70-30 copper-nickel, cobalt, ferritic and martensitic stainless steels, and nickel and nickel alloys; those of lowest resistance are copper and copper alloys, magnesium and magnesium alloys, plain carbon steels and silver and silver alloys. Tables.

City, June 28, 1955. ASTM Special Technical Publication No. 179, 1956, 19-26.

Tests indicate that, except for pH, water composition within range of variables studied has minor influence on corrosion rates of carbon steel and stainless steel under conditions which may exist in primary coolant of water-cooled and moderated reactors. Water conditions cannot be considered unimportant because: range of variables studied was limited by induced radio-activity and radiation stability of possible corrosion inhibitors; special corrosion cases in system may exist in which water composition or treatment may be important; and effect of water condition on corrosion product may be greater than its effect on corrosion rate.

Corrosion of Aluminum in High Purity Water. R. J. LOSSINGER and J. M. ARWOD. *Corrosion*, 13, No. 9, 582-584 (1957) Sept.

In-reactor corrosion rates of 1245 and 2024 aluminum alloys were determined in demineralized water at temperatures up to 200 C. A correlation between corrosion rates and the effective aluminum surface temperature is presented. The effect of increased hydrogen ion concentration on corrosion rates is also discussed. 14196

Investigations on the Reaction of Aluminium with Water. (In German.) D. ALTENPOHL *Aluminium*, 33, No. 2, 78-91 (1957) February.

As a result of chemical reaction of aluminum with boiling water a hydrated oxide: $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}^{100}$, or boehmite layer is formed on the metal surface, which, if certain conditions of the reaction are satisfied, may be used as a means of general corrosion-protection. The author conducted extensive research to determine the conditions which are capable of producing maximum corrosion resistance of such boehmite layers. To this effect the influence of minute differences in the purity of boiling water, the formation of boehmite films by the repeated use of the same water and the effect of various additions to super purity water, together with the pH value, on the rate of growth of such layers, was studied. Finally, the suitability of boehmite layers produced in an alkaline medium for corrosion-protection was investigated. The protective value of the films formed under different conditions was tested by exposing the samples to tap water of various temperatures. The results are summed up as follows: (1) colorless boehmite layers formed in water of less than 1.5% German hardness provide full protection against corrosion by tap water at temperatures higher than 70 C; (2) the aggressivity of tap water increases with decreasing temperatures; (3) at room temperature and up to 50 C only the films produced under optimum conditions remain resistant. Boehmite layers formed by boiling for 2 to 4 hours in a 0.1 N ammonium hydroxide solution proved to have the highest protective value. Such samples tested for 1½ years in cold, running or stationary, hard tap water, showed no traces of corrosion whatsoever. However, the presence of heavy metal ions, in a proportion higher than 1 mg/l of water, especially when the boehmite film is interrupted by minute discontinuities, considerably reduces its protective effect.—ALL. 13696

Factors in the Evaluation of the Corrosivity of Waters. (In Italian.) G. ROMBARA AND F. GIANNI *Metallurgia Italiana*, 48, 503-512 (1956) Nov.

Natural waters and inhibited waters and solutions studied for effects on ordinary construction steel at ambient temperature. Concludes impossibility of defining corrosivity of an electrolytic medium on a given metal unless all corrosion conditions specified; that most

adequate method appears to be determination of break point on cathode polarization curve. 11 references.—MR. 13502

Corrosion Studies in High Temperature Water by a Hydrogen Effusion Method. M. C. BLOOM, M. KRULFELD, W. A. FRASER and P. N. VLANNES. *Corrosion*, 13, No. 5, 297t-302t (1957) May.

A new method for the measurement of static corrosion rates in aqueous systems at elevated temperature and pressure is briefly described. Data obtained by application of the method to ferrous systems are presented. These data include (1) the corrosion rate of low carbon steel in distilled water at 600 F. (2) the effect of raising the pH in such systems, (3) the effect of thermal shock and of temperature rise on the corrosion rate, and (4) the effect of heat treatment of the metal on the corrosion rate. Comparison between the corrosion rates of low carbon steel and stainless steel and some data are included on the effect of the wall thickness of low carbon steel specimens on the rate of hydrogen effusion resulting from corrosion at 600 F.

The Preparation and Maintenance of High-Purity Water. F. N. AUGUST. Paper before American Society for Testing Materials, 58th Annual Meeting, Symposium on High Purity Water Corrosion, June, 1955. Am. Soc. Testing Materials, Special Technical Publ., No. 179, 1-7 (1956). Available from: A.S.T.M. 1916 Race Str., Philadelphia 3, Penna.

High-purity (H.P.) water, used as a coolant and moderator, is prepared and maintained by an ion-exchange system which is an integral part of the reactor. H.P. water is defined as a water free of all solids, liquids and gases, and is measured in terms of electrical resistance. In the analysis of water, a list of determinations in order of importance is given. H.P. water exposed to high-energy radiations forms hydrogen peroxide and hydrogen. The susceptibility of various metals to crevice corrosion in H.P. water containing oxygen is given. Ion exchange resins for removing oxygen are discussed, and the mixed-bed de-ionization described. The preparation of ion-exchange water for corrosion-testing is also outlined.

*Mathematical Treatment
of Glass Corrosion Data*

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Am. Cer. Soc. Jnl.

45:178-81 Apr. 1, 1962

Special Corrosion Study of Carbon and Low-Alloy Steels. R. U. BLASER AND J. J. OWENS. Paper before Am. Soc. Testing Materials, 58th Ann. Mtg., Symp. on High-Purity Water Corrosion, Atlantic City, June 28, 1955. ASTM Special Technical Publication No. 179, 1956, 37-53; disc., 54-55. Available from Am. Soc. Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.

Tests to determine quantitative corrosion data on carbon and low alloy steels in high purity water to permit their application in nuclear reactor systems. Description of water conditions and apparatus for high velocity and static tests up to 750 F and 3500 psi, quantitative data and metallographic and visual observations of specimens are presented. Water conditions are based on deaerated, deoxygenized, distilled water. Small quantities of gas and/or chemical treatment are added for certain work. Five materials tested are A 212, A 179, A 83-52T (carbon steels), A 335 P11 and A 335 P 22 (chromium-molybdenum steels). Results for A 212 carbon steel at 600 F under static conditions and at 30 ft./sec. are plotted. Total corrosion and iron which went into water and that which remained as an oxide film before descaling are shown separately. Results show that corrosion is highest for clean specimen at start of test and that corrosion rate decreases rapidly with time of exposure. Specimens in semi-static water retain more scale and have lower corrosion rate and loss of iron to water than specimens at high velocity. Advantages of pH control are shown. Some reduction of initial high heat transfer rates as result of corrosion and/or deposition is reported.

Stress Corrosion Tests of Stainless Steels in High Temperature Waters. R. B. NIEDERBERGER. Naval Engineering Experiment Station, Annapolis, Maryland, Rept. EES-040028M, Feb. 15, 1956, 17 pp.

Laboratory stress corrosion tests, using U-bend specimens exposed in the liquid and vapor phases of chloride bearing boiler water at 500F, have been conducted with Type 304 stainless steel, stress relieved at 900F and at 1700F after preparation of specimens, Type 430 stainless steel, Carpenter 7 molybdenum steel, and with a group of 6 austenitic steels containing nickel in amounts ranging from 10 to 40%. Stress corrosion cracking occurred in vapor exposed specimens of all materials except Type 430 stainless steel. The results confirm the conclusion that austenitic stainless steels as a class are subject to stress corrosion cracking in high temperature waters containing chloride and oxygen. (auth.)

Susceptibility of AISI 410 to stress corrosion and means of eliminating the stress-corrosion problem. Henry Suss (General Elec. Co., Schenectady, N.Y.). *U.S. At. Energy Comm. KAPL-2155*, 64 pp.(1961).—AISI 410, tempered below about 1100°F., is susceptible to stress-corrosion attack in high-temp., high-purity H₂O, and should not be used in pressurized-H₂O reactors. Shot peening, which produces a compressive surface layer, protects AISI 410 from stress corrosion. When the alloy is tempered at 1125-1350°F. for 2-4 hrs., it becomes immune to attack. Factors believed to contribute to the immunity are changes in the microstructure in the grain boundaries, formation of rounded pits instead of sharp pits, and relief of stress. Cr electroplating offers no protection against pitting attack, and should not be used for the protection of AISI 410 and similar alloys.

Patricia Pain

Corrosion on the inner surface of steel gas pipelines. Yu. I. Bokserman, K. S. Zarembo, and E. P. Okhrimenko. *Tr. Vses. Nauchn.-Issled. Inst. Prirodn. Gaz.* 1959, No. 8, 304-39. —The materials used for pipelines and conditions of the inner surfaces under conditions in practice are reviewed. Lab. tests were made with steel coupons for 3 months to det. the corrosion rate in moist gas and in condensate polluted with H₂S and CO₂. An app. in which tests were made for 7 months under exploitation conditions is described. The rate of attack was 1 g./sq. m.-day. The corrosion products were analyzed. Suggestions are made for the solution of the corrosion problem.

4.61-15 WATER CORROSION OF STRUCTURAL MATERIALS. A. H. Roebuck. Paper before Engrs' Soc. Western Penn., 15th Ann. Water Conf., Pittsburgh, October 18-20, 1954. *Proc. 15th Ann. Water Conf.*, 1954, 167-177; disc., 177-185.

Summarizes results of tests to determine corrosion resistance

of stainless steels and other metals in high purity, high temperature water to aid in selecting structural materials for atomic reactor system. Tests were carried out in high pressure autoclaves and circulating systems using high pressure pumps, all Types 347 or 304. Factors influencing corrosion that were studied include temperature, water purity and chemical additions, dissolved gas concentration (oxygen), velocity, pressure, surface preparation, heat treatment, amount of metal working, galvanic coupling, geometry of test sample, and imposed stress. Crevice corrosion, effect of pH, and chloride stress cracking are considered in the discussion. Data are given for austenitic, ferritic, heat resisting, martensitic, and precipitation hardening stainless steels, and nickel, inconel, Monel, Hastelloy, 70-30 copper-nickel, Stellites, and Duranickel among others. Tables, graphs.

*Book: "Corrosion" T. P. Hoar,
International Sci. & Tech.
Dec. 1963*

4.6.1-6 CORROSION OF IRON IN HIGH-TEMPERATURE WATER. PART I. CORROSION RATES BY HYDROGEN EVOLUTION AT 240 TO 360° C. PART II. KIRKENDALL EXPERIMENTS. D. L. Douglas and F. C. Zyges. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-1376, November 1, 1955, 93 pp.

A new method of measuring the corrosion rate of metals in high-temperature water was developed. The method involves determining the amount of hydrogen evolved in the reaction. Corrosion measurements are carried out in small autoclaves, the gas space of which is filled with a known amount of a carrier gas, helium. After corrosion, a sample of the gas is taken, and is analyzed on the mass spectrometer. From the analysis and the amount of gas the hydrogen evolved in the corrosion reaction is readily calculated. Using this method, extensive measurements were made of the corrosion of Armco iron and high-purity iron over the temperature range 240 to 360° C. The effects of surface finish, temperature, and heat-treatment were studied. In addition, measurements were made in saturated vapor, superheated vapor, and certain dilute aqueous solutions. Electrolytically or chemically polished surfaces corrode at a rate that is very low compared with the rougher pickled surfaces. At 240° C the corrosion rate is low and constant with time. At 316° C and 360° C the corrosion behavior is best described by the cubic law, $m = k_1(t + k_2)^{3/2} + k_3$, where m is the amount of hydrogen evolved, t is the time, and k_1 , k_2 and k_3 are constants. An unexplained spread in the data prevented the determination of the constants, but the total corrosion for electropolished specimens ranged from about 0.5 to 1.0 millimoles of hydrogen evolved per square decimeter in 100 hours. No significant difference between Armco iron and the high purity iron was found. Also, no effect of temperature in the range 316 to 360° C was detected. Corrosion behavior is the same in saturated vapor, superheated vapor, and the dilute solutions. Annealing the iron for a few hours at 800° C in hydrogen or a vacuum somewhat increased the corrosion rate. These results are discussed in terms of a mechanism involving diffusion of iron ions through a magnetite film. At 240° C the rate-determining step is postulated to a Schikorr-type reaction, $3 \text{Fe(OH)}_2 \rightarrow \text{Fe}_3\text{O}_4 + \text{H}_2 + 2 \text{H}_2\text{O}$. At the higher temperatures from iron ion diffusion is likely to be rate-determining. Kirkendall-type experiments were carried out in order to identify the ion species diffusing through the magnetite film formed on corrosion of iron in high temperature water. (auth.)

4.6.2-5 THE PREPARATION OF DISTILLED WATER AS BOILER FEED WATER. C. H. Allen. Paper before Soc. Chem. Ind., Sym. on Distillation, London, April 3, 1950. Chemistry & Industry, No. 37, 772-774 (1951) Sept. 15.

Method used at Plaistow Wharf Refinery for softening of water required for evaporation is the lime-soda-sodium aluminate process, precipitating the scale forming salts of calcium and magnesium. After filtering, the evaporators are protected from corrosion by removal of oxygen by deaeration and the use of sodium sulphite. The general method of inhibiting caustic embrittlement is by maintaining an optimum ratio of sodium sulphate to sodium hydroxide. Graph and diagrams are included 3 references.

4.6.1-2 CORROSION IN BORATED AND DEIONIZED WATER AT TEMPERATURES UP TO 500° F. W. L. Boyd and Robert S. Peoples. Battelle Memorial Institute. U. S. Atomic Energy Commission Pubn., BMI-1047, October, 1955, 20 pp.

The effects of applied stress, contact, and crevices on the corrosion of stainless steels, Be, and Al alloys in distilled and borated waters at temperatures up to 500° F were studied. Also, the corrosion resistance of Be when an external heat flux was applied, was determined in boiling distilled H₂O.

4.6.1-1 INTERIM REPORT ON THE CORROSION BEHAVIOR OF SOME BORON CONTAINING MATERIALS IN HIGH TEMPERATURE WATER. Donald C. Belouin and Ulrich Merten. Knolls Atomic Power Lab. U. S. Atomic Energy Comm. Pubn., KAPL-M-UM-4, Sept. 9, 1955, 12 pp. Available from Office of Technical Services, Washington, D. C.

The corrosion resistance of stainless steel-boron, Ti-B, and Zr-B alloys to H₂O at 600° F was investigated. Boron powder dispersions were also corrosively tested.

4.6.1-7 AN ECONOMIC ANALYSIS OF WATER TREATMENT. M. C. Forbes. Petroleum Engr., 27, No. 10, C34, C36-C37, C40-C42 (1955) September.

Defines the problems to be faced in an economic analysis of water treatment, evaluates the results of using a treatment of less than maximum effectiveness, and aids in estimating costs of chemicals and equipment. Specific problems of microbiological control, scale control and corrosion control are considered. Mechanical treatment by aeration, deceleration, sedimentation and filtration, and chemical treatment by hot lime-soda softening and ion exchange are analyzed. Graphs present cost data for lime-soda, sodium zeolite and hydrogen zeolite softening systems. Addition of chromium salts as corrosion inhibitors is discussed.

4.6.1-5 CORROSION OF METALS IN HIGH TEMPERATURE WATER AT 500° F AND 600° F. S. C. Datsko and Calvin R. Breden. Argonne Nat'l. Lab. and Babcock and Wilcox Co. U. S. Atomic Energy Comm. Pubn., ANL-5354, Oct., 1954, 203 pp.

Results of corrosion tests on a variety of metallic alloys obtained during the period from February, 1949 through July, 1953 are summarized. The corrosion behavior of a series of structural materials, which included zirconium and zirconium

alloys, was investigated. Several water treatments not generally used were employed in an attempt to minimize corrosion, and the effects of these treatments are discussed. Several materials, such as the 300 series stainless steels and certain types of zirconium, have been found to be satisfactory at both 500 and 600° F in all environments in which they were tested. Other materials were found to be satisfactory under specific conditions. At 500° F the addition of over 50 cc of hydrogen per liter of water permits the widest selection of materials. (auth.)

4.6.1-17 PREVENTION OF CORROSION BY WATER IN OIL REFINERIES. Peter W. Sherwood. *Corrosion Technology*, 1, No. 4, 113-115, 120 (1954) June; *Werkstoffe u. Korrosion*, 5, No. 5, 168-172 (1954) May; *Petroleum* (London), 18, No. 2, 50-53 (1955) Feb.

Prevention of corrosion by water is the most important item of preventive maintenance in petroleum refineries. This problem is encountered in innumerable forms and no one solution satisfies all the requirements of a single refinery. Broad field of protection from water corrosion takes in underground storage tanks which are to be spared attack from soil water, prevention of corrosion in heat exchangers due to sweet or brackish cooling water, and protection of exposed metallic structures from rain water. Cathodic protection, metallic coatings, organic coatings, inhibitors, alteration of environment and metallurgical selection are major methods of corrosion control.

4.6.1-4 FUNDAMENTAL OBSERVATIONS ON THE SIGNIFICANCE OF OXYGEN IN THE PURIFICATION OF WATER AND IN CORROSION-PROTECTION. L. W. Haase. *Werkstoffe u. Korrosion*, 1, No. 1, 4-9 (1950).

The physical and chemical properties of various types of water are discussed, together with the relationships between the corrosive action of water and the degree and nature of its purification. The corrosion of metals exposed to water depends not only on the amounts of free carbon dioxide and metallic salts contained in the water, but also on its free-oxygen content. If the oxygen content is low, e.g., when organic matter is present metal goes readily into solution; protective films form on the metal surfaces only when the amount of free oxygen present is not less than 5 mg per l.

4.6.1-4 CORROSION TESTS FOR ARGONNE NATIONAL LABORATORY: FINAL SUMMARY REPORT. S. C. Datsko. Research Center, Babcock and Wilcox Co., BW-5313, August 31, 1953, 18 pp.

The corrosion behavior of a series of structural materials in 500 and 600° F water, which included zirconium and zirconium alloys, was determined. Several methods of water treatment were employed in attempting to minimize the corrosion of the materials. The detailed results of these tests were included in 40 reports issued during the course of the work and listed in the bibliography of this report which summarizes the work. (auth)

4.6.1-14 CORROSION OF STAINLESS STEELS IN SUPERCRITICAL WATER. H. A. Pray and W. K. Boyd. Battelle Memorial Inst. U. S. Atomic Energy Commission Pubn., BMI-901, Feb. 4, 1954, 20 pp.

The corrosion behavior of 10 stainless steels (representing hardenable and nonhardenable grades) has been determined by static tests in degassed supercritical water at 800, 1000, and 1350° F at a pressure of 5000 psi. The materials were evaluated on the basis of weight gain and metallographic examination of samples after exposure to the selected test conditions. The Armco 17-4PH, Armco 17-7PH, and Hastelloy F alloys were the most resistant materials at both 1350 and 1000° F. Inconel X, Type 302 stainless, and Allegheny A-286 were severely attacked at both 1350 and 1000° F, whereas the Hastelloy X and Type 410 stainless show heavy attack at 1350° F only. The type 347 stainless steel, although exhibiting only moderate weight gains, was severely pitted after exposure at 1350° F. Some pitting was also observed on the sample of Type 309 stainless. In supercritical water + hydrogen at 1000° F, the Allegheny A-286 alloy was the only material showing a significant reduction in corrosion resulting from the presence of hydrogen. All the alloys tested had excellent resistance to 800° F degassed supercritical water after an 84-day exposure. In general, the corrosion in degassed supercritical water at 1350° F was intergranular in nature, whereas at 1000° F only the Inconel X material was selectively penetrated along grain boundaries. All alloys suffered some decarburization and carbide precipitation after exposure at 1350° F. No decarburization or significant phase changes were observed for samples exposed at 1000° F. (auth.)

4.6.1-16 PERFORMANCE OF MATERIALS TESTED IN WATER AT HIGH TEMPERATURE. W. G. Schreitz and C. J. Lancaster. U. S. Naval Eng. Expt. Station Rept., EES-4A(14)-966870, 1951 (unclassified 1954), 18 pp. (on micro-cards).

Results are presented of corrosion and stress-corrosion tests on materials tested in a dynamic corrosion apparatus and in a hydraulic loop. 30-day tests were made in the former with the specimens under a static bending load, rotating at a peripheral velocity of 11 ft./sec. in oxygenated water at 500° F (260° C). Stress-corrosion tests were carried out with the materials stressed to 0.25 X U.T.S. in degassed water at 600° F (315° C); the water was circulated at 25 ft./sec. for 3-4 days. Materials tested in the dynamic loop included Inconel-X, aluminum bronze, and alloy Carpenter 20 (chromium 20, nickel 29, molybdenum 2, copper 3%, balance iron) while in the hydraulic loop nickel, Inconel, and Monel, were tested. Corrosion rates for the nickel-base alloys were much higher than for austenitic steels. However, K Monel showed a weight gain in the unannealed condition; in the precipitation-hardening condition this alloy showed the maximum weight loss of all the nickel alloys. The aluminum bronze showed the greatest weight loss of all the alloys studied.

M. Shenk. Aluminum and Water, *Metal-oberfläche Ausgabe*, 4, 3, 33-36 (1952) March.

Role of oxide film: electrochemical nature of corrosion resistance of aluminum to various types of water, such as rain water, fresh water, sea water and distilled water. Reasons for corrosion resistance; nature of the different types of corrosion; main constituents likely to be harmful to aluminum.

6.4.2-37 AQUEOUS CORROSION OF 2S ALUMINUM AT ELEVATED TEMPERATURES. J. E. Draley and W. E. Ruther. Argonne Nat'l. Lab. U. S. Atomic Energy Comm. Pubn., ANL-5001, Feb. 1, 1953, 41 pp.

2S aluminum corrodes uniformly in nearly pure water at rates which increase with temperature. The reaction is characterized by an initial period of relatively rapid corrosion, followed by a linear slow rate of corrosion. The slope of the linear part of the curve, or the corrosion rate, changes from about 0.05 to 1.3 mil/yr average penetration rate from 125 to 200° C. Above 200° C intergranular attack occurs, with resultant more rapid penetration and deterioration of the metal. The corrosion rate can be reduced and apparently the intergranular attack can be prevented by the addition of an acid to the water. The solution pH of minimum corrosive attack on aluminum goes down with increasing temperature. It is of the order of 6.5 at 50° C and 2 at 315° C. At all temperatures above the boiling point of water the corrosion rate is less in dilute acid solutions than in neutral water. Sulfuric acid has generally been used for adjusting the acidity of water. Presumably other acids would be satisfactory except that no halogen ions should be added. Corrosion in slightly alkaline solutions (pH 8.5) is more rapid than in neutral water at nearly all temperatures. At 100° C the difference shown in stagnant tests is very slight but increases considerably if the temperature is increased to the order of 200° C. Presumably the effect of solution flow rate would be marked in the case of alkaline water; much more so than in neutral water. The corrosion of 2S aluminum does not appear to eliminate it as a material of construction in contact with pure water up to about 200° C. In dilute acid, properly controlled, it is probable that aluminum could be used to considerably higher temperatures. The temperature limitation has not yet been determined in this environment. (auth)

4.6.2-6 WATER CORROSION OF STRUCTURAL MATERIALS; OCTOBER, 1948—JUNE, 1951. C. R. Breda, S. Greenberg, R. M. Robinson, A. H. Roebuck, V. F. Saitta and C. C. Scott. Argonne National Lab., July 15, 1951, 198 p. (Report-4519).

A program of evaluating the corrosion resistance of materials considered for use in high-temperature water systems has been undertaken. Results of laboratory corrosion tests completed by Argonne and its subcontractors before June 1, 1951, on structural materials other than zirconium are presented. The materials studied include stainless steels, carbon steels and other ferrous alloys, cobalt alloys, nickel and nickel alloys, copper and copper alloys, other metals and alloys, and ceramic bodies.

T. J. Barendregt, and K. H. Brakstad. Corrosion and Impurities in the Heavy-Water System of the Dutch-Norwegian Reactor. Joint Establishment of Nuclear Research, Kjeller, Norway. *Nuclear Engineering* (Part 1, Chem. Eng. Progr. Symposium Ser.) 11, 183-187 (1954).

The design and performance of the JEEP reactor is briefly discussed. Results of corrosion and impurity checks on aluminum canning are given. Laboratory experiments with distilled water in an autoclave for 100 hours indicated that type 2S aluminum was the most resistant to corrosion. The corrosion effects in the reactor were mainly caused by D₂O contamination. Inspection of the valves, pumps and heat exchanger of the D₂O system showed corrosion attacks on the stainless steel, which resulted in rust particles in the system. An increase in conductivity and decrease in the pH of the system indicated the presence of impurities. Results of an analysis of the D₂O system for impurities and causes of radioactivity after operation are given.

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6.4.2-128 STATIC CORROSION OF ALUMINUM ALLOYS AT 350° F. AND 480° F. IN DISTILLED WATER.
P. O. Strom and M. H. Boyer. U. S. Atomic Energy Comm. Publ., LRL-64, Oct., 1953, 10 pp.

The static corrosion of a number of Al alloys in distilled water has been studied at 350° F. (175° C.) and 480° F. (250° C.) for periods up to 1500 hr. The following alloys were tested: 24S, 61S, 52S, Alclad 24S, Alclad 75S clad with 72S. Sheet specimens were prepared by sandblasting, cleaned in boiling acetone, and soaked for 16 hr. in distilled water; testing was carried out in stainless steel bombs with Teflon spacers. Weight gains were recorded, and the thickness of the corrosion product was calculated assuming a formula of $Al_2O_3 \cdot H_2O$. At 350° F. the film was extremely adherent and chem. inert; a similar film was formed initially at 480° F. Later, however, at the higher temp., the film became spotty and black and grew over the entire surface; it was non-adherent and non-protective. The black film formed more easily on the 24S alloy than on 61S or Alclad 24S. At the lower temp. attack was uniform, with general surface roughening; at the higher temp. this was also the case on 61S. Extensive local pitting of 24S occurred at 480° F. At the lower temp. the initial rate of attack was high for all the alloys, especially 52S, but thereafter the rates were <0.3 mil/year. At 480° F. attack was more rapid with 61S and Alclad 24S, showing ultimate rates of 1-3 mils/year; 24S alloy could not be studied for >500 hr. The thickness of the initial protective film was temp.-dependent, being of the order of 0.6 mg./cm.² at 350° F. and four times this at 480° F. 11 ref.

6.4.2-36 AQUEOUS CORROSION OF 2S ALUMINUM AT ELEVATED TEMPERATURES. J. E. Draley and W. E. Ruther. Argonne National Lab. U. S. Atomic Energy Comm. Pubn., AECU-2301, October, 1952, 9 pp.

The corrosion characteristics of 2S aluminum in water at elevated temperatures was studied. It was found that the aluminum corrodes uniformly in nearly pure water at rates which increase with the temperature. Normal corrosion is not rapid up to well over 250° C, but the usefulness of the material might be limited by intergranular attack which may become important at a temperature above 200° C.

6.4.2-122 ALUMINUM AND WATER. M. Schenk. *Metaloberfläche*, Ausgabe B, 4, No. 3, B33-B36 (1952) March; Translation: Aluminium Labs. Rept. No. B-TM-143-54.

Role of oxide film; electrochemical nature of corrosion; corrosion products: Corrosion resistance of aluminum to various types of water, such as rain water, fresh water, sea water, and distilled water. Reasons for the existence of corrosion resistance; nature of the different types of corrosion; and the main constituents likely to be harmful to aluminum.

S. L. Williams. Power Plant Coolant Technology Program. *Transactions A.S.E.S.*, July 5, 1957.

Brief summaries of studies of high temperature water purification; corrosion product distribution and activity build-up; coolant sampling techniques; high pH effects; coolant deaeration, chemical treatment and radiation catalyzed reactions. Fission product contamination and removal are described.

Ross C. Tucker. Corrosion and the Destination of Corrosion Products in a High Pressure Power Plant. *Corrosion*, 14, 209-212 (1958) May.

Methods used to reduce corrosion in a high-pressure steam generating plant are reviewed. Factors involved in the formation, transportation and deposition of corrosion products within the plant's cycle are discussed in detail. Attention is given in the discussion to such matters as water conditioning, feed water and steam concentrations, corrosion of steam lines, turbine blade deposits, the collecting of dissolved gases in condensers and dissolved oxygen scavengers. Under certain low load operations and shutdown periods, the chemist may have relatively little control over the corrosion occurring.